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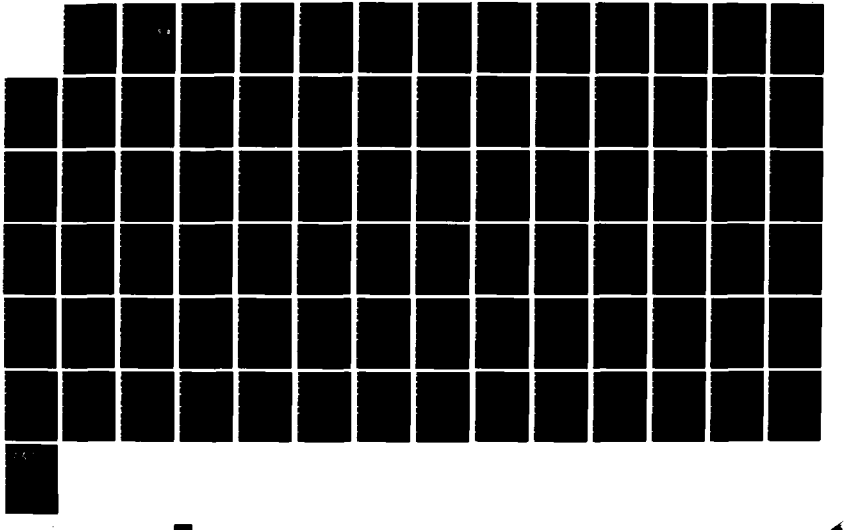

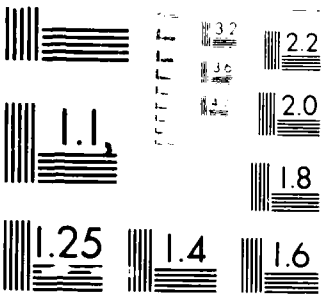

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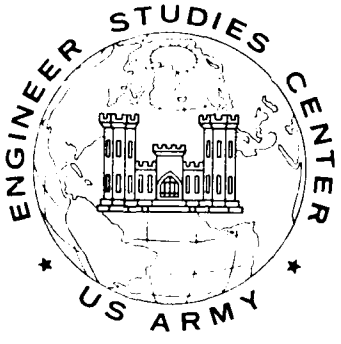
A USERS GUIDE TO MILITARY HYDROLOGY



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This report is a guide to military planner's who have an operational interest in the field of military hydrology. It focuses on recent literature and doctrine which apply to military hydrology and indicates which agency or who is responsible for various tasks in the field of military hydrology. Only unclassified sources are treated. A bibliography of selected military hydrology citations is included.

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US Army Corps of Engineers

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Graphics were prepared by Ms. Sandra L. Hodge. Publication was coordinated by Mr. Christopher Y. K. Lew. The text was edited by Ms. Mary L. Scala. This report was prepared for publication by Ms. Stacia L. Hall, Mrs. Theresa A. Hardesty, Mrs. Donna L. Norbutt, and Ms. Heather A. Plancon, under the supervision of Ms. Donna M. Craine.

CONTENTS

ABBREVIATIONS AND ACRONYMS

ACE.....Assistant Chief of Engineers
AD.....armored division
ADE.....Assistant Division Engineer
AFR.....Air Force regulation
AR.....Army regulation
ARTY.....artillery
ASL.....Atmospheric Sciences Laboratory

BEES.....Battlefield Environmental Effects System
BRADC.....Belvoir Research and Development Center

CCM.....cross-country mobility
CE.....Corps of Engineers
CENTCOM.....US Army Central Command
CERL.....US Army Construction Engineering Research Laboratory
COE.....Chief of Engineers
CONUS.....Contintental United States
CRREL.....US Army Cold Regions Research Laboratory

DA.....Department of the Army
DCD.....Directorate of Combat Developments
DCSLOG.....Deputy Chief of Staff, Logistics
DCSOPS.....Deputy Chief of Staff, Operations
DIA.....Defense Intelligence Agency
DME.....Directorate of Military Engineering
DMS.....Defense Mapping School
DOD.....Department of Defense
DOTD.....Directorate of Training and Development
DSB.....Defense Science Board
DTIC.....Defense Technical Information Center

EL.....environmental laboratory
ERADCOM.....US Army Electronics Research and Development Command
ESC.....US Army Engineer Studies Center
ETB.....engineer topographic battalion
ETL.....US Army Engineer Topographic Laboratories

FAWPSS.....Forward Area Water Positioning Supply System
FC.....field circular
FM.....field manual
FORSCOM.....US Army Forces Command

HEC.....US Army Hydrologic Engineer Center
HECSA.....Humphries Engineer Center Support Activity

HHC.....headquarters and headquarters company
HQ.....headquarters

ID.....infantry division
IPB.....Intelligence Preparation of the Battlefield

JCS.....Joint Chiefs of Staff

LOG.....logistics
LOGCTR.....logistics center

ME.....Middle East
MED.....medical
MET.....meteorological
MP.....miscellaneous paper
MR.....miscellaneous report

NCEL.....Naval Civil Engineering Laboratory
NO.....number
NTIS.....National Technical Information Center

PAM.....pamphlet
POC.....point of contact
POL.....petroleum, oil, and lubricants
PUB.....publication

QSTAG.....Quadriparte Standard Agreement

R.....report
R&D.....research and development
RDJTF.....Rapid Deployment Joint Task Force
ROWPU.....Reverse Osmosis Water Purification Unit

SEC.....section
ST.....student text
STANAG.....standard agreement
SUPR.....supplemental reading
SWA.....Southwest Asia

TAC.....terrain analysis center
TB.....technical bulletin
TM.....technical manual

TOE.....table of organization and equipment
TP.....technical paper
TR.....technical report
TRADOC.....US Army Training and Doctrine Command
TSG.....The Surgeon General
TUSA.....Third US Army
TWDS.....Tactical Water Distribution System
TOPO.....topographic

US.....United States
USA.....US Army
USAES.....US Army Engineer School
USAICS.....US Army Intelligence Center and School
USAQMS.....US Army Quartermaster School
USALOGC.....US Army Logistics Center
USAREUR.....US Army, Europe

VMI.....Virginia Military Institute

WDRT.....water detection response team
WES.....US Army Waterways Experiment Station
WRDB.....water resource data base
WRMAG.....water resources management action group
WRST.....water resources support team

A USERS GUIDE TO MILITARY HYDROLOGY

1. Purpose. This report is a comprehensive, quick access guide to literature, agencies, and points of contact (POCs) in the field of military hydrology. It is designed to help users find the information they need to carry out operational missions and studies related to military hydrology.

2. Scope. This guide:

a. Reviews recent unclassified US Army doctrine, reports, and literature published primarily between 1970 and 1986 about and including information on military hydrology.

b. Lists military agencies and POCs responsible for various aspects of the military hydrology mission.

c. Suggests where more information can be found.

d. Provides a selected military hydrology bibliography.

3. Background. In May 1979, the US Army Waterways Experiment Station (WES) began publishing a series of reports which address problem areas in the field of military hydrology. In May 1984, the US Army Engineer Studies Center (ESC) published Engineer Troop Well Drilling Rig Requirements, a study which outlined the specific kinds of equipment the Army needed to purchase if it was to meet the requirements of its military hydrology mission worldwide. During both efforts a large amount of data were gathered about various aspects of military hydrology and water supply systems. However, gathering, assembling, and assimilating new and old doctrinal literature and policies are not enough. Some effort must be made to determine what information is most useful to accomplishing specific tasks within the Army's military hydrology mission. Therefore, ESC decided to assemble, summarize, and consolidate the data collected during these prior studies and publish this report on current

military hydrology literature and POCs. This will give members of the Army and joint services easy access to previous work, and help them avoid duplicating past efforts.

4. Limitations and Their Significance. This guide has several limitations:

a. LIMITATION: The data and information reviewed in this guide are presumed correct and adequate. SIGNIFICANCE: ESC did not attempt to rate documents for currency and adequacy, or to recommend which documents should be updated or expanded.

b. LIMITATION: This guide does not provide data or information on geographically site-specific hydrologic information. SIGNIFICANCE: This report only guides the user to where information related to military hydrology can be found. For site-specific data, users must access the water resources data base maintained by the US Army Engineer Topographic Laboratories (ETL).

c. LIMITATION: This guide only includes information published between 1970 and October 1986. SIGNIFICANCE: Any data or doctrine currently being written or developed have not been included.

5. Definitions.

a. Hydrology. That part of the terrestrial environment concerned with the characteristics of surface and subsurface water.

b. Military hydrology. A specialized field of hydrology that deals with those characteristics of surface and subsurface water that may affect the planning and conduct of military operations.[1]

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[1] Military Hydrology, Army Regulation (AR) 115-21 (Department of the Army, Headquarters [DA HQ], 24 March 1977).

c. Soil moisture content. Soil moisture content is the amount of water in a given volume (or weight) of soil.[2] Of primary interest is its impact on runoff, streamflow, trafficability, and facility site selection.

d. Meteorology. The study of the Earth's atmosphere, including movements and other phenomena, especially as they relate to weather forecasting.[3] The military hydrologist must have accurate measurements and forecasts to estimate streamflow, soil moisture, and the availability of water and water sources.

e. Streamflow. Streamflow is a type of channel flow. Specifically, it is the surface runoff traveling within a stream.[4] Streamflow information helps the military hydrologist forecast floods and streams and to suggest the best way to manage gap crossings and dam breaches.

f. Water supply. Water supply is a source, means, or process of providing water. In the context of this study, it is the supply of water to the US armed forces. The military hydrologist must be able to the locate, identify, and extract potential water sources for soldier in the field.

6. Approach. The first step in the preparation of this guide, as indicated in Figure 1, was to conduct a literature search. ESC examined Department of the Army (DA) Pamphlet 310-4 for Army technical manuals (TMs), field manuals (FMs), Army regulations (ARs), technical bulletins (TBs), and other related doctrinal publications which include military hydrology or water supply in their title or subject list. A search was also done of various automated data bases available from the Defense Technical Information Center

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[2] Proceedings of the Military Hydrology Workshop, 17-19 May 1978 Vicksburg, Mississippi, Technical Report EL-79-2 (US Army Engineer Waterways Experiment Station [WES], May 1979).

[3] Glossary of Geology (American Geological Institute, 1974), p. 448.

[4] Glossary of Geology p. 699.

MILITARY HYDROLOGY GUIDE APPROACH

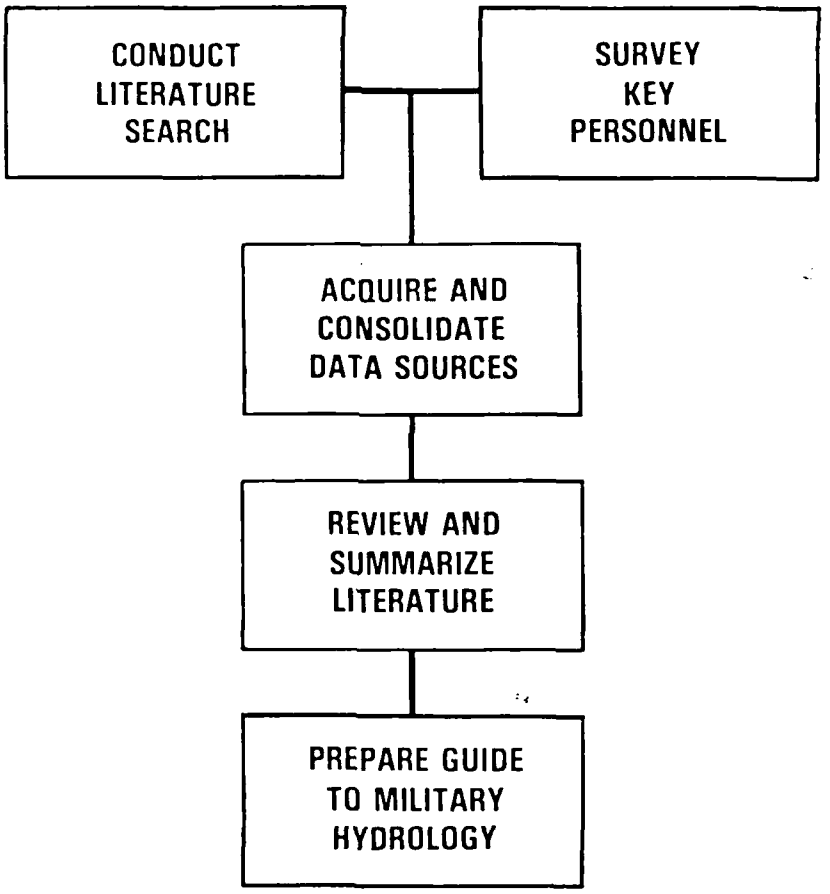

Figure 1

(DTIC), the National Technical Information Service (NTIS), and DIALOGUE, an automated information data base. Various US Army and Department of Defense (DOD) libraries, as well as the libraries of research and development (R&D) laboratories that publish reports related to military hydrology, were also examined. These sources were reviewed to find information not only on the topic of military hydrology, but on the use and applications of military hydrology. The next step (Figure 1) was to query various key personnel involved in compiling reports and doctrine relating to military hydrology. This information was then consolidated and summarized.

7. Presentation. Figure 2 lists each document reviewed, grouped by five subject categories: organization, meteorology, soil moisture, streamflow, and water supply. These reviews are summarized, by subject, in paragraph 8. Paragraph 9 outlines the POCs available, by subject, in the military hydrology community. Annex A abstracts the military hydrology information contained in each doctrinal or technical publication reviewed by ESC; the page number for each abstract is listed in the last column of Figure 2. Annex B is a complete bibliography of the source material used to prepare this guide.

8. Military Hydrology Literature Analysis.

a. Introduction. Traditionally, the military hydrologist performs a range of tasks relating to identifying and assessing hydrologic systems in the environment, and assisting in setting up and managing water supply systems in the field. Specifically, the terrain analyst is responsible for collecting, compiling, and professionally evaluating information on the physical characteristics of watersheds, river channels, flood plains, and water control structures. An assistant divisional engineer, working with the division's G2/3 planner, will analyze hydrologic data to appraise the streamflow

SUMMARY OF MILITARY HYDROLOGY LITERATURE

Document Name	Title	Subject Categories: Organization	Meteorology	Soil Moisture	Streamflow	Water Supply	Annex A Page No.
Doctrine:							
AR 115-10/ AFR 105-3	Meteorological Support for the US Army	X	X				A-2
AR 115-12	US Army Requirements for Weather Service Support	X	X				A-3
AR 115-21/ AFR 105-10	Military Hydrology	X					A-4
AR 700-136	Land Based Water Resources Management in Contingency Operations	X					A-5
FC 5-545	Geology			X	X	X	A-6
FM 5-30	Engineer Intelligence		X	X	X	X	A-7
FM 5-35	Engineers Reference and Logistical Data	X	X	X	X	X	A-8
FM 5-100	Engineer Combat Operations	X					A-9
FM 5-104	General Engineering	X				X	A-10
FM 5-105	Topographic Operations		X	X	X	X	A-11
FM 5-146	Engineer Topographic Units	X					A-12
FM 5-166/ AFR 85-23	Well Drilling Operations			X		X	A-13

Figure 2 (Continued on Next Page)

SUMMARY OF MILITARY HYDROLOGY LITERATURE (Continued)

Document Name	Title	Subject Categories					Annex A Page No.
		Organi-zation	Meteo-rology	Soil Moisture	Stream-flow	Water Supply	
FM 5-335	Drainage			X	X		A-14
FM 6-15	Field Artillery Meterology	X	X				A-15
FM 10-51-1	Commanders Handbook for Water Usage in Desert Operations	X				X	A-16
FM 10-52	Field Water Supply	X			X		A-17
FM 21-10	Field Hygiene and Sanitation	X			X		A-18
FM 21-32	Topographic Support	X					A-19
FM 21-33	Terrain Analysis		X	X	X	X	A-20
FM 30-10	Military Geographic Intelligence (Terrain)		X	X	X	X	A-21
FM 34-81/ AFM 105-4	Weather Support for Army Tactical Operations	X	X				A-22
FM 90-3	Desert Operations	X					A-23
FM 90-13	River Crossing Operations		X		X		A-24
FM 101-10-1	Staff Officer's Field Manual Organizational, Technical, and Logistical Data	X					A-25

Figure 2 (Continued on Next Page)

SUMMARY OF MILITARY HYDROLOGY LITERATURE (Continued)

Document Name	Title	Subject Categories					Annex A Page No.
		Organi-zation	Meteo-rology	Soil Moisture	Stream-flow	Water Supply	
TB 5-550-1	Flood Prediction Services		X	X	X		A-26
TB 5-550-2	Compilation of Intelligence on Military Hydrology		X	X	X		A-27
TB 5-550-3	Flood Prediction Techniques		X	X	X		A-28
TB MED 577	Sanitary Control and Surveillance of Field Water Supplies	X				X	A-29
TM 5-235	Special Surveys				X	X	A-30
TM 5-330/ AFM 86-3	Planning and Design of Roads, Airbases, and Heliports in the Theater of Operations			X			A-31
TM 5-813-2	Water Supply: Water Sources			X	X	X	A-32
TM 5-818-5/ AFM 88-5	Dewatering and Groundwater Control			X	X		A-33
TRADOC PAM 525-11	US Army Operational Concepts for Near Term Water Resources Management	X					A-34
TRADOC PAM 525-32	US Army Operational Concept for Water Support in a Theater of Operations	X					A-35

Figure 2 (Continued on Next Page)

SUMMARY OF MILITARY HYDROLOGY LITERATURE (Continued)

Document Name	Title	Subject Categories: Organization	Meteorology	Soil Moisture	Streamflow	Water Supply	Annex A Page No.
Reports:							
BRADC R-2403	The Use of Geophysical Surface Methods for Military Groundwater Detection			X	X	X	A-36
CERL-TR-M-287	Theater of Operations Construction in the Desert: A Handbook of Lessons Learned in the Middle East					X	A-37
CERL-WES-PUB	Troop Construction in the Middle East					X	A-38
DMS ST-025	Stream Hydrology			X	X		A-39
ETL-TAC MISC 01-85	User Requirements Analysis for the Worldwide Water Resources Data Base	X					A-40
ETL TR-0207	Terrain Analysis Procedural Guide for Geology			X	X		A-41
ETL TR-0285	Terrain Analysis Procedural Guide for Drainage and Water Resources			X	X		A-42
ETL TR-0344	Synthesis Guide for River Crossings				X		A-43
HEC TP-92	Hydrologic Engineering Center Planning Models	X		X	X		A-44
NCEL TR-1637	Desert Water Supply	X				X	A-45
WES MP EL-79-6	Military Hydrology Series Reports 1-13	X	X	X	X	X	A-46

Figure 2

characteristics that may affect river crossing operations. The military hydrologist will also be called on to estimate the extent and probable hydraulic effects of artificial floods that might be created by the demolition of high dams or by the manipulation of regulating gates or control structures. Most recently, the Army's emphasis on operations in arid environments has made the location, extraction, and supply of water important Army missions. Since these are integrated tasks, they would most likely be solved by a team of military logisticians, engineers, and planners. Sorting out and locating the military hydrologic data required to solve these tasks can be difficult even if one knows where to look, and nearly impossible if one does not know what sources of information are available.

b. Consolidated wrap-up of military hydrology literature. The following paragraphs summarize the information available about the military hydrology categories listed in Figure 2.

(1) Organizations. The requirements of the AirLand Battle doctrine and arid-environment operational contingency plans have made it important for the Army to delineate its water-related responsibilities. The result has been a number of documents related in part to military hydrology, and which define Army organizational and operational procedures in the field of military water supply and support. These include US Training and Doctrine Command (TRADOC) pamphlets (PAMs) 525-11 and 525-32, AR 700-136, FM 5-100, FM 5-104, and FM 5-105. Typical water supply system deployments are pictured in TRADOC PAM 525-11. Water requirements are outlined and established by both the US Army Construction Engineer Research Laboratory (CERL) and WES publications and by TRADOC PAM 525-11. TRADOC PAM 525-11 also reflects the recent transfer of water supply proponency to the logistics branch. Engineer

missions for military hydrology are defined in FM 5-104 and FM 5-105. FM 5-104, FM 5-105, and FM 5-146 establish the responsibilities for developing for water resources data bases. The terrain teams' responsibilities with respect to military hydrology are outlined in FM 5-105 and FM 90-13; these responsibilities include gathering military hydrologic planning data for gap and river crossings, obstacles, and avenues of approach.

(2) Meteorology. The US Army does not maintain any significant capability for weather data gathering and dissemination. Weather support to the US Army is provided by the US Air Force as defined by AR 115-10 and AR 115-12. Tactical meteorologic applications are found in FM 6-15 and FM 34-81.

(3) Soil moisture. Few documents detail how soldiers can obtain data about soil moisture content, or explain how to use the soil moisture data included in hydrologic models. Most doctrine and literature focus solely on soil moisture as it relates to trafficability and cross-country movement. Such information is found primarily in FM 30-10, FM 21-33, and TM 5-330; little is found in other manuals. However, the relation of soil moisture to runoff (and therefore to streamflow) is important to the military hydrologist. Soil moisture also plays an important role in helping to locate support facilities.

(4) Streamflow. Hydrology literature on streamflow emphasizes training terrain analysts. A student text prepared by the US Army Defense Mapping School (DMA) and two technical reports prepared by ETL provide a "how to" approach to water resources analysis. A comprehensive military hydrology manual outlining and consolidating current applications, techniques, and technology has not been produced, although information on the current documentation of military hydrology applications can be found in FM 90-13, FM 5-104,

FM 5-105, and FM 21-33. Most of these manuals describe how to determine stream channel characteristics for crossing operations, or outline the role of surface drainage features as obstacles to movement. ETL has documented water resources data base specifications and information in Miscellaneous Report (MP) number 01-85.[5] The ETL Terrain Analysis Center (ETL-TAC) is the primary DOD proponent for military water resources information. ETL-TAC operates a water resources data base (WRDB), as well as managing a water detection response team (WDRT). The resources of both the WRDB and WDRT can be used by all the armed services.

(5) Water supply. Most advances in doctrinal documentation and technological modernization have been in the area of water supply. The need to satisfy potable water requirements in arid environments has forced the Army to seek new solutions. New water supply technology for the Army has surfaced and has been implemented under the auspices of the Water Resource Management Action Group (WRMAG). Water source detection has been enhanced by advances in research conducted by WES and the Fort Belvoir Research and Development Center (BRADC). ETL-TAC has formed a water resources data team. Water purification capabilities have been greatly enhanced by the introduction of various Reverse Osmosis Water Purification Units (ROWPU); TRADOC PAMs 525-11 and 525-32 both contain ROWPU information. Water distribution has been improved by new bladders and Tactical Water Distribution Systems (TWDS).

9. Military Hydrology Points of Contact. The real measure of the military hydrologist's success in obtaining data is whether he or she knows where to look or who to ask. ESC put together a library of POCs on military

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[5] User Requirements Analysis for Worldwide Water Resource Data Base, ETL-MR-0185 (US Army Engineer Topographic Laboratories (ETL), January 1985).

hydrology from sources listed in AR 115-21 and recent WRMAG meeting minutes. This library is organized into five categories: functional responsibility, research and development, training, operations, and data collection and analysis.

a. Functional responsibility. The Joint Chiefs of Staff have assigned the Chief of Staff of the US Army responsibility for military hydrology for the US armed forces.[6] In turn, the Army Chief of Staff has made the Chief of Engineers (COE) responsible for performing the functions and activities of military hydrology. The Assistant Chief of Engineers (ACE), Military Engineering and Topography Branch, has the engineer staff responsibility for monitoring military hydrology activities. Figure 3 shows these relationships and responsible agents.

b. Research and development. The COE (through the ACE) provides the R&D required to improve the military hydrologic capabilites of the armed forces. Various US Army Corps of Engineers R&D labs research, test, and develop technology to improve the military hydrology capabilitiy of the US Army. The US Army Cold Regions Research Engineering Laboratory (CRREL) solves the special problems of military hydrology in cold regions. CERL solves problems of water treatment, storage, supply, and facility construction in fixed installations. WES is charged with R&D in the areas of hydraulics, hydraulic prediction and forecasting models, and flood assessment. WES also tests and evaluates commercially available hardware items that maintain and improve the effectiveness of well drilling teams and terrain teams. Although not tasked directly with military hydrology engineering, the US Army Hydrologic Engineering Center (HEC) can do hydrologic modeling. Figure 3 lists responsible R&D laboratories and their respective centers, divisions, systems, and teams.

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[6] Military Hydrology, AR 115-21 (DA HQ, 1977)

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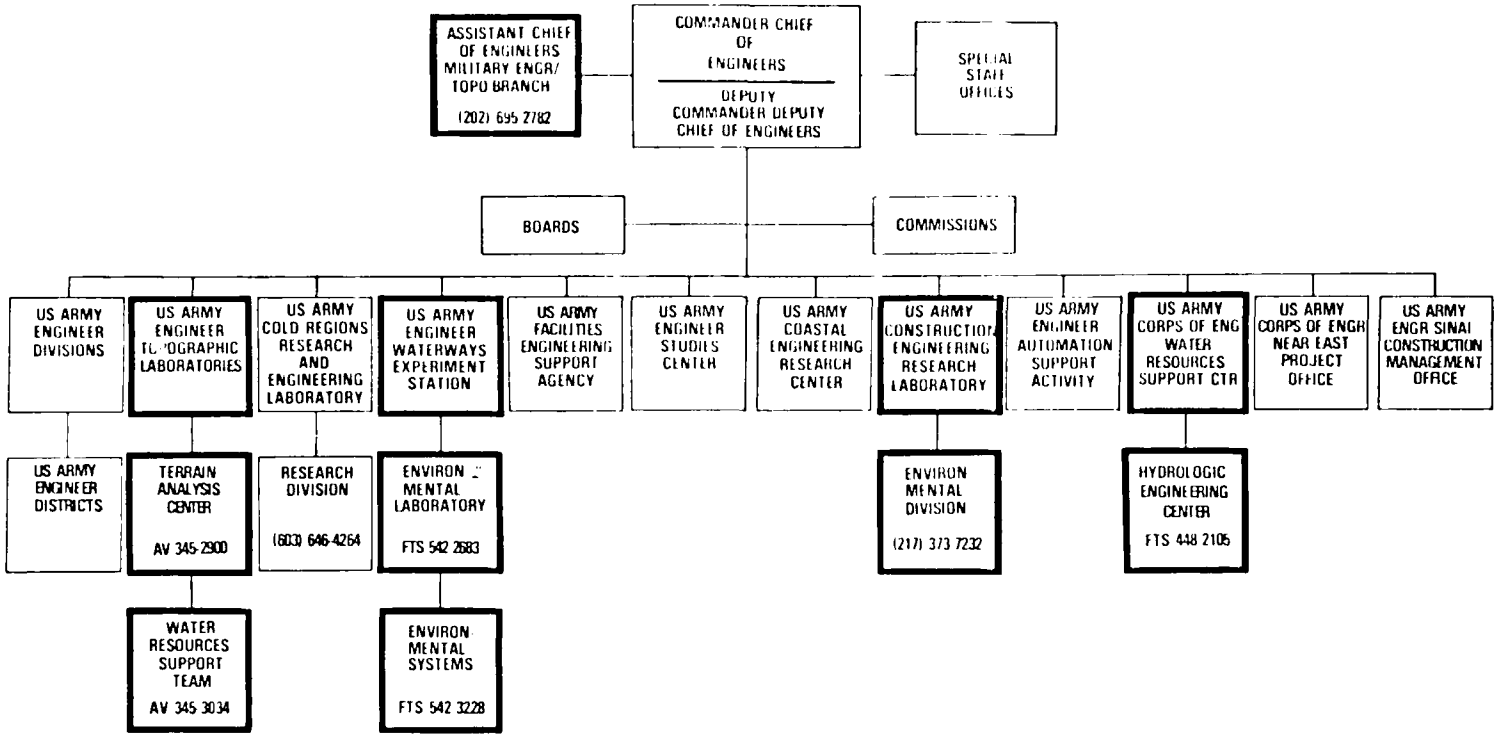

Figure 3

c. Training. The Commanding General of TRADOC is responsible for validating the requirements for improved military hydrologic capabilities for the Army, for establishing doctrine, and for training Army personnel to perform these functions.[7] Currently, the Defense Mapping School (DMS), through its terrain analysis courses, trains enlisted personnel and provides doctrinal instruction to members of the armed forces. The US Army Engineer School (USAES) also plays an important role by training officer personnel and by developing military hydrology doctrine. Three branches within USAES are charged with military hydrology responsibilities. The USAES Directorate of Combat Developments (DCD) is involved with conceptual development of equipment; the USAES Directorate of Training Developments (DOTD) writes doctrine for the application and use of that equipment. The USAES Department of Military Engineering (DME) directs instruction and supervises the occasional compilation of field manuals which may affect military hydrology. Figure 4 shows the structural relationship of various training elements involved.

d. Operations. The Commanding General of the US Army Forces Command (FORSCOM) is responsible for the readiness of Army engineer units to perform military hydrologic functions in operational situations.[8] FORSCOM trains terrain teams in the technical aspects of military hydrology and in various levels of hydrologic collection and application. These teams are located at theater-army level (TOE 5-336), corps level (TOE 5-540IJ) and division level (TOE 5-540IK). The theater army team is in general support; teams assigned to corps and division are direct support teams. US Army engineer officers in the assistant divisional engineer's office, as well as personnel in the assistant

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[7] Military Hydrology, AR 115-21 (DA HQ, 1977).
[8] Military Hydrology.

MILITARY HYDROLOGY TRAINING/DOCTRINAL DEVELOPMENT

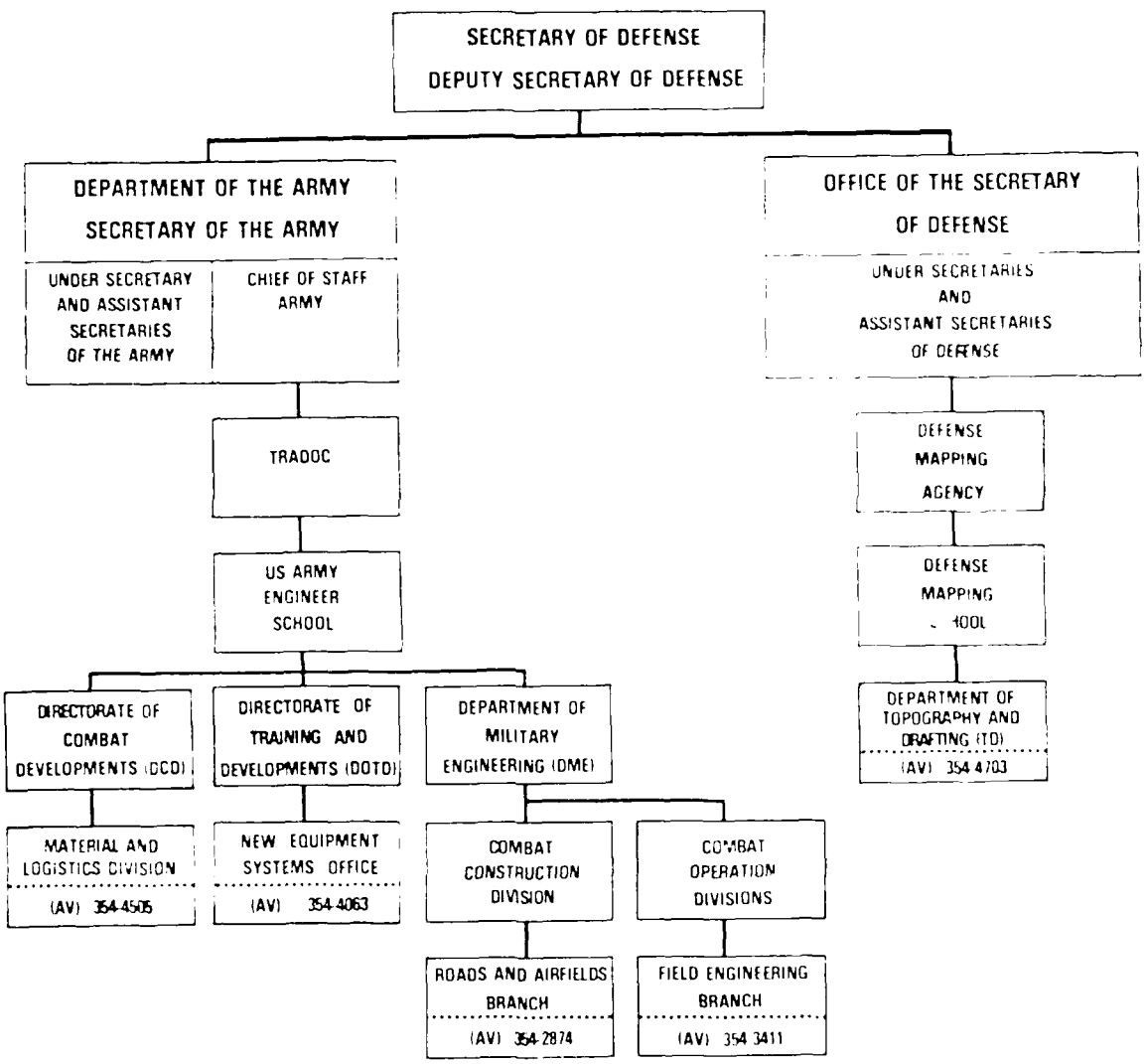

Figure 4

corps engineer offices, may also provide a source of expertise. Figure 5 shows typical terrain team and engineer staff support in USAREUR.

e. Data collection and analysis. The COE is responsible for collecting and analyzing hydrologic data and disseminating the hydrologic information required by the US armed forces. The COE has delegated this responsibility to the Water Resources Support Team (WRST) of ETL-TAC. TAC maintains water resources data base as a joint armed service resource in CONUS. Figure 3 shows the relationships among ETL, TAC, and WRST within the US Army Corps of Engineers. Data collection and analysis are done in the field through terrain teams.

10. Observations.

a. There is no single consolidated FM or TM that delineates and outlines all aspects of military hydrology. There also is no real "how to" manual. The last substantial effort to consolidate military hydrology was a collection of bulletins published by the US Army Corps of Engineers in the late 1950s.

b. The Army has begun to develop doctrine for water supply operations, outlining both responsibilities and equipment use, especially for arid environments. USAES, the US Army Quartermaster School (USAQMS), and the US Army Logistics Center (USALOGC) will update and rewrite outdated and needed doctrine. This is being done under the auspices of the WRMAG.

c. TRADOC PAMs 525-11 and 525-32 document potable water requirements for Army personnel, and describe how to satisfy those requirements through the Army's water supply system during field operations. WES, BRADC, USALOGC, and other Army laboratories are developing systems to facilitate water detection, extraction, and to solve water storage problems.

USAREUR ENGINEER ORGANIZATION (TOPO)

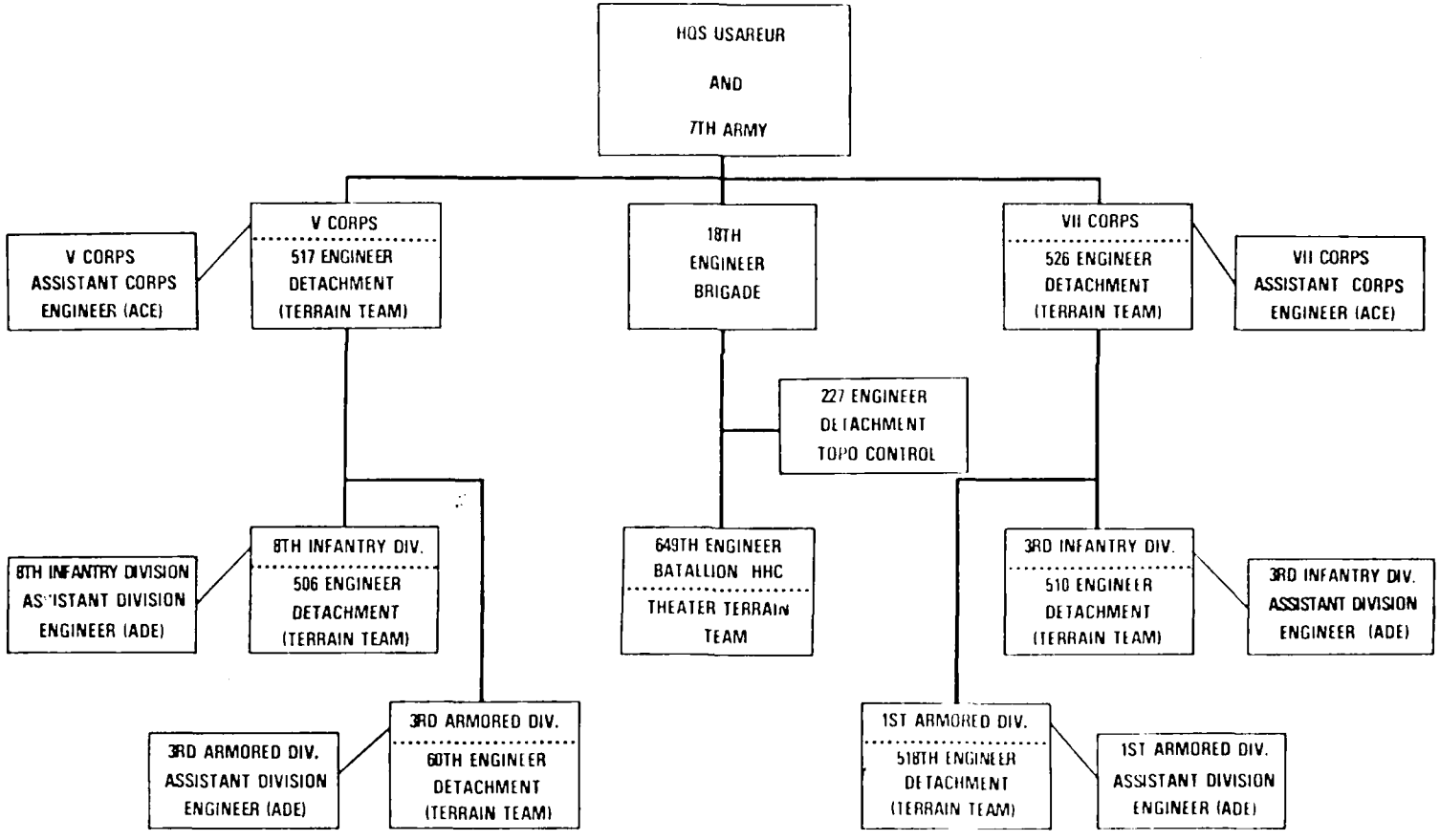

Figure 5

d. The best source for site-specific military hydrologic data is either the terrain team located in the area of operations, or the WRDB maintained by ETL-TAC. Personnel in the Environmental Systems Division at WES are the best source of information about new developments in the field of military hydrology. In addition to publishing a series of reports on military hydrology, WES also maintains a resident military hydrologist.

LAST PAGE OF MAIN PAPER

ANNEX A

MILITARY HYDROLOGY LITERATURE SUMMARY

ANNEX A

MILITARY HYDROLOGY LITERATURE SUMMARY

1. Purpose. This annex reviews and summarizes individual documents that pertain to the field of military hydrology.

2. Scope. The document review timeframe is 1970-1986. A few documents published prior to that time period are included. FMs, TMs, TBs, and other published reports and literature are included. The document review is limited to unclassified documents and documents to that are currently published. Some document summaries have been incorporated from previous WES military hydrology reports. Literature and doctrine in draft or review form are not included.

AR 115-10/AFR 105-3
Meteorological Support for the US Army
September 1980

Purpose

This regulation provides policy and direction to Army and Air Force elements engaged in meteorological support of the Army.

Summary

This revision updates Army weather and other meteorological support requirements. It clarifies Army and Air Force responsibilities for providing meteorological support to the Army, the functions and relationships of the Staff Weather Office and Army Intelligence Officer, responsibilities for providing communications for acquisition and dissemination of weather information, and related administrative and logistical support.

AR 115-12
US Army Requirements for Weather Service Support
January 1978

Purpose

This regulation describes policy and procedures to be followed by Army commanders in requesting weather service support. This support is further described in AR 115-10/Air Force Regulation (AFR) 105-3 and FM 34-81.

Summary

This regulation outlines the procedures for preparing US Army requirements for weather service support and the submission of these requirements through channels to the Department of the Army and, thence, to the Department of the Air Force in accordance with AR 115-10/AFR 105-3. Army meterological support requirements, such as meteorological observations for direct support of Army weapons systems and meteorological support of Army research, development, test and evaluation activities, are not addressed by this regulation.

AR 115-21/AFR 105-10
Military Hydrology
May 1977

Purpose

This regulation defines the scope of military hydrology and assigns responsibility for providing hydrologic information to the US armed forces.

Summary

This regulation assigns the Chief of Staff, US Army, the responsibility for military hydrology for the US armed forces by authority of the Joint Chiefs of Staff. The Chief of Staff, US Army, has assigned to the Chief of Engineers (COE) responsibility for performing the functions and activities which are divided into two parts: those dealing with research and development and those dealing with support of operational elements.

All research and development activities relating to military hydrology are the responsibility of the COE. In the Continental United States (CONUS) and other territories of the United States, the COE is responsible for providing military hydrology services and functions required for direct support of operational elements. In theaters of operation and overseas commands, terrain analysis elements of Army forces are responsible for providing military hydrologic information to all deployed units. Where no terrain analysis elements are present or available, staff engineers are assigned this responsibility.

AR 700-136
Land Based Water Resources Management in Contingency Operations
1 November 1984

Purpose

AR 700-136 sets policy and procedures for water resources management in support of contingency operations. It defines the Army's role in joint contingency operations and outlines responsibilities for water support.

Summary

This regulation assigns land based water resources management responsibility to appropriate Army proponents. The Deputy Chief of Staff for Logistics (DSCLOG), the Deputy Chief of Staff for Operations (DCSOPS), the Surgeon General (TSG), and the COE all share common responsibility for carrying out the water supply mission. This regulation supersedes AR 115-20 (Field Water Supply). This regulation does not apply to fixed installations, water support operations, or civil works emergency water management.

FC 5-545
Geology
April 1986

Purpose

The purpose of this manual is to relate the science of geology to military engineering. It is to be used for both reference and training. The manual is not intended to make geologists out of military engineers, but rather to present some of the geologic principles required for the correct solutions of many military engineering problems.

Summary

This manual includes a survey of basic geologic materials, features, and processes. It further describes the geologic factors that affect the properties and occurrence of natural construction materials; the construction of dams, tunnels, roads, airfields, and bridges; the location of water supplies, and terrain evaluation. Chapter 5, "Groundwater," treats several aspects of how groundwater relates to water supply.

FM 5-30
Engineer Intelligence
September 1967

Purpose

This manual is a training text and general reference for all personnel concerned with engineer intelligence. It serves as a guide for commanders and their staffs in understanding the purpose and scope of engineer intelligence and how the engineers may be utilized to meet their intelligence requirements.

Summary

The information in this manual deals with the concept and role of engineer intelligence both in the zone of the interior and in the theater of operations. In Chapter 9, pages 41-43, various topographic and intelligence teams are listed and described in terms of capability, basis of allocation, strength, and mobility. These teams have been reorganized under table of organization and equipment (TOE) 5-540. The new TOE and a discussion of mission and control is presented in FM 5-146, Engineer Topographic Units, chapter 3. In particular, Team IL, Military Hydrology, is no longer in existence. The military hydrology capability now is the responsibility of the terrain teams as set forth in TOE 5-336, TOE 5-540 IJ, and TOE 5-546 IK.

FM 5-35
Engineer's Reference and Logistical Data
April 1971

Purpose

This manual is intended to provide engineers and other military personnel with a compilation of data for use in the planning of engineer activities.

Summary

This FM includes data pertaining to engineer troops, equipment, construction materials, and to all types of engineer troop tasks, to include use of soils, construction of drainageways, roads, railroads, bridges, ports, airfields, and heliports. Petroleum, oil, and lubricant (POL) distribution, barrier and denial operations, fortifications, protective structures, camouflage, general construction, and mapping services are also covered. On page 13-1, the manual addresses water supply and distribution. Although the water resources mission has been transfered to the logistics branch, a section on water sources is included. A small section that relates to hydrology is listed as water supply on page 18-12.

FM 5-100
Engineer Combat Operations
May 1984

Purpose

FM 5-100 is the Army's keystone how-to-fight manual for combat engineers. FM 5-100 presents basic doctrine. It implements the AirLand battle doctrine described in FM 100-5, which sets forth the concepts for winning the battles and campaigns in modern warfare.

Summary

The information in this manual guides the use of engineers in a theater of operations. It addresses how units are assigned and employed in combat zone and communications zone operations that affect forward areas. FM 5-100 is intended for commanders, staffs, and trainers at all levels. References to military hydrology are found predominately under the topographic engineering and general engineering sections. Specifically, pages 10-9, 11-8, and A-74 address the mission and organizational aspects of conducting engineer-related water tasks under desert and contingency operations.

FM 5-104
General Engineering (Draft)
April 1985

Purpose

This manual provides the doctrinal basis for the planning and execution of general engineering tasks in the theater of operations. General engineering is described as those tasks which do not directly contribute to the mobility, countermobility, or survivability of committed manuever elements.

Summary

FM 5-104 is a doctrinal manual discussing the following general engineering functional areas: lines of communication, construction and repair, establishment and maintenance of installations, logistics facilities support, construction materials, and other related missions. This FM is part of a new series of engineer doctrine. Chapter 12 is devoted to water supply. This chapter specifically defines the water supply missions the engineer maintains, and the integration of those tasks into the total water supply mission. Specifically, seven major engineer responsibilities are delineated with regards to water supply operations; four pertain directly to military hydrology. These are reconnaissance, identification and compilation of data pertaining to surface water sources, compilation of data using existing information to establish recommended well-drilling sites to obtain sub-surface water, and well drilling.

FM 5-105
Topographic Operations (Draft)
1985

Purpose

This manual sets forth the fundamental doctrine regarding topographic engineering support to the Army.

Summary

This manual describes the role of topographic engineers in the AirLand battle arena, and the support that they will be expected to render. Topographic engineer functions and products are placed into three categories: terrain analysis, topographic production, and map distribution and storage. Topographic operations are described from peacetime and wartime scenarios, including the management and factors affecting those operations. Topographic organization and equipment is discussed. The key to military hydrologic information in the field is the terrain analyst. Obtaining and collecting data on hydrologic information, as well as processing and updating data bases containing that information, is the responsibility of the terrain analyst. The terrain analyst utilizes this information to accurately portray military aspects of terrain input to the Intelligence Preparation of the Battlefield (IPB) process. Obstacles, key terrain, and avenues of approach analysis all utilize military hydrologic information.

FM 5-146
Engineer Topographic Units
September 1979

Purpose

This manual presents doctrine and guidance on the mission, organization, capabilities, and employment of engineer topographic units. It is designed to guide staff officers and unit commanders responsible for directing and conducting topographic operations and training.

Summary

In Figure 1-1, page 1-2, terrain teams are shown as being placed at echelon above corps (EAC) or theater army, corps, and division levels. The theater army team is part of the headquarters and headquarters company (HHC) of the engineer topographic battalion (TOE 5-336); the corps terrain team is separately organized under TOE 5-540 IJ. One terrain team, TOE 5-540 IK, is assigned per division. Specific duties pertaining to military hydrology are covered on pages 3-8 and 3-9. These duties include the collection of data via the hydrologic survey set and the interpretation and analysis of these data.

FM 5-166/AFR 85-23
Well Drilling Operations
June 1975

Purpose

The purpose of this manual is to serve as an introductory text on groundwater usage and water well-drilling operations. It is primarily intended for military personnel responsible for developing groundwater as a water source in the field, but it may also be used for guidance in drilling water wells for permanent military installations. Auxiliary uses of water well-drilling equipment, such as providing geologic or soil data, are also covered. This manual may be used as a text for training personnel in groundwater usage, water well-drilling operations, and related uses of the associated equipment.

Summary

The most important aspects of groundwater, including its origin, occurrence, quality, and exploration are covered in this manual. Well construction methods most frequently used by military organizations (the rotary and downhole techniques) are covered, and miscellaneous methods are presented for use when standard military well-drilling equipment is not available. Several types of equipment and methods normally used only in civil practice but which may in certain situations be adopted for military use are also described. The techniques of completing, developing, and testing wells after the hole has been drilled are presented. Arctic well construction and its unique problems are discussed, and the auxiliary uses of well-drilling equipment for rock and soil sampling are covered. The different types of pumps that are used to lift water from inside a well to the surface are also described.

FM 5-335
Drainage
December 1985

Purpose

The purpose of this field manual is to provide information and guidance necessary for engineers responsible for planning, designing, and constructing drainage facilities in the theater of operation. The manual was developed for military forces in the field and emphasizes useful methods for field operations.

Summary

Although this manual was designed to provide information required to design adequate drainage systems, Chapters 2 and 8 of the 11 chapters are of interest to the military hydrologist. Chapter 2, "Drainage Hydrology," introduces the hydrologic cycle and the basic principles of storms and their related rainfall and runoff. Additionally, procedures for determining storm frequencies and duration are treated. A section on hydrographs and an explanation of their basic elements (baseflow, lag times, peak flow) is provided. Chapter 8, "Subsurface Water," presents an introductory guide to standards for constructing subsurface drainage facilities. The principles of locating subsurface water, flow of water, and the effects of subsurface water are of primary interest.

FM 6-15
Field Artillery Meterology
August 1978

Purpose

This manual addresses the meteorological requirements of the field artillery.

Summary

This manual covers all the tasks required to select a meteorological station site and to prepare and deliver artilley meteorological messages. This FM relates only indirectly to military hydrology problems. Chapter 3 discusses meteorology. An artillery meteorological section is assigned to each artillery brigade operating independently. Each meteorological section consists of 11 people trained in some of the fundamentals of weather observation. If meteorological sections were required to obtain rainfall measurements in addition to other duties, these rainfall measurements would be of value to the hydrologists; however, the problem of communication of these data is a factor to consider.

FM 10-51-1
Commanders Handbook for Water Usage in Desert Operations
May 1983

Purpose

This handbook explains the importance of water in desert operations. The handbook is designed for the unit commander.

Summary

The handbook gives specific guidance on water supply planning, protecting the water supply, and surviving under emergency conditions in a desert. In addition, this handbook contains basic data on various pieces of water-related equipment. This pocket-sized handbook offers some basic common sense information on water usage.

FM 10-52
Field Water Supply
February 1985

Purpose

The purpose of this manual is to provide personnel with a reference for field water supply in combat operations and training exercises, where water is treated and supplied by mobile equipment. It is also a reference for Army medical personnel who inspect and improve water sources and treated water.

Summary

This manual covers water quality, water sources, common water treatment processes, and procedures for reconnoitering and setting up water points. It presents procedures for operating water purification points and supply points. It also discusses general support distribution systems and environmental influences on water supply operations. The latter include special procedures for arctic, tropic, and arid battlefields, and for actively contaminated portions of the integrated battlefield. Chapter 2, "Raw Water Supplies," and Chapter 3, "Water Reconnaissance," contain data that may be of interest to the military hydrologist.

FM 21-10
Field Hygiene and Sanitation
July 1970

Purpose

This manual provides information and instruction in the use of established, practical measures designed to preserve health and prevent disease in the Army and Air Force.

Summary

This manual explains the fundamentals of sanitation and their application under field conditions. It points out the responsibilities of command and of the individual soldier for knowing and observing the rules of sanitation and hygiene, especially as they apply to living conditions and to circumstances peculiar to the military service. Chapter 4, "Field Water Supply," deals with the procurement and treatment of water from surface, ground, and other water sources. It outlines the sanitary considerations that should be weighed when selecting various water sources.

FM 21-32
Topographic Support
September 1979

Purpose

This manual sets forth the fundamental doctrine regarding topographic support to the Army. It provides the topographic specialist, as well as the support unit or individual user, with the objectives of topographic support, what it consists of, and how it is carried out.

Summary

On Figure 2-2, page 2-4, the placement of terrain teams within the national topographic community is shown.

On page 4-8, Figure 4-2, the position of the terrain teams with the engineer topographic battalion (ETB) is shown.

According to information presented in page 4-10, the headquarters and headquarters company (HHC) of the ETB contains one terrain team available for theater general support. One corps terrain team is assigned to the battalion for each support corps in direct support of the corps. Also, a division terrain team will be in direct support of each division and assigned to the parent corps terrain team.

FM 21-33
Terrain Analysis
May 1978

Purpose

This manual is intended to assist in identifying the duties of the terrain analyst and to serve as a reference.

Summary

The manual was written for an enlisted terrain analyst and is used as part of the terrain analyst course for enlisted grades E5 to E7.

Terrain analysis is the process of analyzing a geographical area to determine the effect of natural and manmade features on military operations. This manual describes the procedures to be followed by the terrain analyst including data collection, management, and use of data files, analysis of terrain factors, preparation of special purpose maps, and preparation and distribution of terrain studies. Chapter 2 "Collect Data," includes discussions of kinds of data and where they can be obtained.

Chapter 5, "Analysis of Terrain Factors," includes the bulk of the material in this manual of interest to the military hydrologist. It is divided into seven sections, of which two are useful: (1) Prepare Climatic Summaries and (2) Analyze Drainage Features. The primary intelligence products developed under the guidelines of sections (1) and (2) are map overlays and supporting data files for each of the six topics. These are sources of information that can be used for military hydrology task completion.

FM 30-10
Military Geographic Intelligence (Terrain)
March 1972

Purpose

FM 30-10 is intended to serve as a guide to the preparation of geographic intelligence products. As such, it describes methods for the collection and interpretation of geographic or terrain data from a variety of sources.

Summary

FM 30-10 treats the geographic aspects of the battlefield as intelligence products and concerns itself with the collection and organization of that intelligence. It is directed to the terrain unit, which has the responsibility for gathering terrain intelligence, and deals at length with the effect of terrain features on military operations. It contains sections devoted to hydrology, water supply, and waterways, and an entire chapter on weather and climate. However, these items are considered only as observables. No attention is given to either their time-variable nature or their predictions. The manual is restricted throughout to the tabulating and reporting of observed conditions.

FM 34-81/AFM 105-4
Weather Support for Army Tactical Operations
August 1984

Purpose

This manual provides doctrinal guidance to US Air Force (USAF), Air Weather Service (AWS), and field personnel, including commanders and staff officers, who are concerned with the weather support required for Army tactical operations. It consolidates and explains US Army and AWS current doctrinal guidance on weather support services and functions provided for field army tactical operations, and provides guidance to field personnel and USAF staff weather officers and AWS personnel operating with field army headquarters and elements. The information is applicable to general war, limited war, cold war, and stability operations.

Summary

Functions and responsibilities are delineated on pages 1-8 and 1-9. Noteworthy is that the tasks of soil trafficability, river stage, and flood forecasts are the responsiblities of the Assistant Chief of Staff for Intelligence. Chapter 2 addresses Army weather information sources: the artillery meteorological section and the terrain analysis technician. Chapter 4, "Army Weather Support," describes what and where the best source of Army meteorological data can be required. Of interest is the description of the role of engineer/artillery survey units (p. 4-3) and imagery interpretation elements (p. 4-4). Engineer topographic units provide streamflow measurements and predict river stages and floods. The engineer flood prediction service relies on weather teams for precipitation forecasts in support of river crossings, air heads, and defensive positions.

FM 90-3
Desert Operations
August 1977

Purpose

The purpose of this manual is to describe how US Army forces fight in the desert. Conditions encountered in the desert will have a profound effect on military operations. Desert operations require, among other things special equipment, special training and acclimatization, and a high degree of self discipline if operations are to be successful.

Summary

This manual describes how to prepare for desert operations, how units fight in the desert, and how combat service support operations function in such an environment. It focuses on the environment and its effects on personnel and equipment, as well as the factors to be considered when preparing for desert operations. Additionally, FM 90-3 details how the desert environment affects various tactical operations. The role of combat service support in an arid environment is also delineated. Due to the major role that water will play in desert operations, added emphasis is given to discussions pertaining to water operations. Page 2-9, addresses the importance of naturally occuring water sources. Page 2-15, describes the affect of water on soldier performance, while pages 4-19 state that finding, developing and if necessary destroying water supplies is a high priority task for engineers. Water as a class of supply, and as combat service support is treated on page 5-9.

FM 9[illegible]
River Crossing Operations
November 19[illegible]

Purpose

This manual provides tactics and techniques for river crossing operations in the offense and retrograde.

[illegible]

This manual applies primarily to deliberate crossings. These are when the crossing [illegible] must have considerable support from other [illegible] level. However, the principles are applicable to higher and lower levels of command. Emphasis is placed on conventional warfare. There are limited discussions of nuclear, chemical, and biological considerations. The requirements for hydrographic information during river crossing operations are outlined on page 2-2[illegible]. This hydrographic information, normally provided by the engineer terrain team, consists of information on existing crossing sites, stream width, depth and velocity, and river bottom conditions. Additional references are made to the role of hydrographic information in the process of planning a river crossing operation.

FM 101-10-1
Staff Officer's Field Manual
Organizational, Technical, and Logistical Data
July 1978

Purpose

FM 101-10-1 is used as a planning guide, providing general planning data for staff officers of all echelons. However, the primary thrust in developing these planning data has been to fulfill the needs of planners at division level.

Summary

Basic TOEs, supply planning data, movement planning data, personnel and administration, engineer planning data, and situationally dependent combat planning factors are covered in this manual. Classification of water as an item of supply is covered in Chapter 3. Requirements for water supply and rates of consumption are found on page 6-6. The information for arid environments has been revised and updated in US Army Training and Doctrine Command (TRADOC) Pamphlet (PAM) 525-11.

TB 5-550-1
Flood Prediction Services
December 1956

Purpose

This bulletin presents a description of typical conditions under which flood prediction and flood warning services should be established for military purposes. It outlines the organizational arrangements and facilities needed to establish and operate such services under alternate circumstances. It also presents information and instructions of a general nature that would be useful in establishing military flood prediction services.

Summary

This bulletin describes conditions under which a flood prediction service should be established and discusses the necessary organizational arrangements and facilities to provide this service. The criteria for the establishment of a flood prediction service are presented in the form of three questions: Will a flood affect the military operations? Will the forecast be of sufficient military value to justify the effort? Is it possible to gather the hydrologic data required to develop the forecast?

The flood prediction services are divided into three types, based on the time of flood crest after the beginning of rise. The Local Flood Prediction Service would be established for small streams, with a time to peak of less than 12 hours. A Regional Flood Predicition Service would be established for an area where the time to peak is between 12 and 30 hours. The Centralized Flood Predicition Service would be established in an area where the time to peak is more than 30 hours.

TB 5-550-2
Compilation of Intelligence on Military Hydrology
Jaunaury 1958

Purpose

This bulletin provides a valuable tool for training personnel and presents the compilation of intelligence on militarv hydrology as a simple checklist procedure.

Summary

This publication is a guide for the compilation of data on militarv hydrology. It provides a list of information items (with examples) required for specific hydrologic subjects. Information lists are provided for the following 12 subject areas: watersheds, river and canal channels, stream and river gages, precipitation gages, bridges, fords and ferries, dams and reservoirs, hydroelectric plants, flood protection structures, navigation locks, irrigation projects, and drainage projects.

TB 5-550-3
Flood Prediction Techniques
February 1957

Purpose

The purpose of this bulletin is to present flood prediction techniques and procedures in a form suitable for military use.

Summary

This bulletin discusses basic hydrology and presents methods for forecasting floods. Of the hydrology manuals used by the Army, this bulletin presents the highest level of technology. Subjects discussed in detail include rainfall, precipitation-runoff relations, streamflow, hydrograph development, unit hydrograph construction, gage relations, flood routing, snow, and radar. Numerous examples are presented.

TB MED 577
Sanitary Control and Surveillance of Field Water Supplies
March 1986

Purpose

This technical bulletin provides preventative medicine information and guidance to military personnel concerned with the location, production, sanitary control, and surveillance of field water supplies on land.

Summary

The nine chapters in this bulletin provide insight into the role of sanitary control in each phase of the water supply cycle. Human requirements for potable water, water sources and water point reconnaissance, water purification, distribution and storage operations, and water conservation are all discussed from the aspect of how to monitor water quality standards. Chapter 4, "Water Sources and Water Point Reconnaissance," contains most of the data of interest to the hydrologist. TB MED 576 treats the sanitary control and surveillance of water supplies at fixed installations. Together TB MED 577 and TB MED 576 replace TB MED 227, Sanitary Control and Surveillance of Water Supplies at Fixed and Field Installations.

TM 5-235
Special Surveys
September 1964

Purpose

This manual is a reference for engineer officers and technicians responsible for the supervision and conduct of special types of surveys, and describes the instruments and equipment to perform special surveys.

Summary

The various survey types discussed include underground surveys (Chapter 2), geologic and pedologic surveys (Chapter 3), land surveys (Chapter 4), hydrographic surveys (Chapter 5), shore-ship triangulation (Chapter 6), magnetic surveys (Chapter 7), and arctic surveys (Chapter 8).

The portions of the manual reviewed were Chapter 3, Sections I (Geology) and II (Pedology), and Chapter 5, Sections III (Streamflow and Stream-Gaging Stations), IV (Stream-Gaging Equipment), and V (Measurement of Streamflow).

TM 5-330/AFM 86-3
Planning and Design of Roads, Airbases, and Heliports
in the Theater of Operations
September 1968

Purpose

The purpose of this manual is to provide information and guidance to personnel responsible for the planning, design, and construction of theater of operations roads, air bases, and heliports. It is designed to be used as a reference handbook as well as a text for training and operations purposes.

Summary

Only the new working draft of Chapter 9, "Soils Trafficability," was reviewed. This chapter covers the description and use of instruments and equipment and also of tests performed to determine trafficability. The range in values of measurable soil parameters is presented. Also, empirical relations used to predict the number of passes over different soils and slopes that tracked and wheeled vehicles can make are presented.

TM 5-813-2
Water Supply: Water Sources
July 1965

Purpose

This manual prescribes the procedures to be followed in obtaining and developing sources of potable water for Army and Air Force installations and for special projects. It describes general investigative procedures to be followed in determining the most feasible means of obtaining the required water supply. It established criteria to be followed in the development of underground or surface supplies, degree of treatment required, and types of pumping equipment to be used.

Summary

Chapters 6, 7, and 8 provide an intelligence checklist for existing water supplies, well supplies, and surface supplies.

Chapter 9 gives the acceptable concentration of contaminants in a water supply.

Chapter 10 covers water supply wells. Subjects discussed included test drilling, well construction, types of housing and pumps to be used, metering of the supplied water, as well as the minimum number of wells required to provide sufficient water, their capacity, and the types of power units required for pumping.

Chapter 11 includes a discussion of well housing and pumping equipment for surface water pumping stations.

TM 5-813-5/AFM 88-5
Dewatering and Groundwater Control
November 1983

Purpose

This manual provides guidance for the planning, design, supervision, and operation of dewatering and pressure relief systems and of seepage cutoff for deep excavations for structures.

Summary

Of the seven chapters in this manual, Chapter 3, "Geologic, Soil, and Groundwater Investigations," and Chapter 4, "Design of Dewatering, Pressure Relief, and Groundwater Control Systems," are of interest. Chapter 3 centers on geologic and soil conditions, groundwater characteristics, and the permeability of previous strata. Notations on the importance of corresponding surface water investigations are made. The first section in Chapter 4, "Analysis of Groundwater Flow," is noteworthy because it introduces the reader to methods of groundwater flow analysis.

TRADOC PAM 525-11
US Army Operational Concepts for Near Term Water Resources Management
June 1981

Purpose

The purpose of this pamphlet is to set forth an operational concept for an interim solution to the problems of providing water supply support to a joint force for land-based combat operations in arid regions.

Summary

This pamphlet begins by discussing the operational concepts for water support by time-phased deployments, and the force planning for water support. These discussions are supported by four major appendices. Appendix A describes water consumption requirements for various units and services. Appendix B outlines the water supply requirements by unit buildup during deployment phases. Appendix C portrays a typical water unit installation map needed to support a joint force in an arid theater of operations. Appendix D closes the pamphlet by describing the organizational models for implementation. The role of engineer well drilling operations is discussed on pages 8, 15, and 20. Figure C-1 presents a typical theater deployment of a water supply system, showing the role that well drilling sites will play. Figure C-12 depicts a well drilling site's typical integration into the water supply system.

TRADOC PAM 525-32
US Army Operational Concept for Water Support in a Theater of Operations
September 1983

Purpose

The purpose of this concept paper is to describe procedures and required resources for the supply of potable water to the Army in the field.

Summary

This concept paper begins with a general outline of operational factors, and lists what Army organizations are responsible for various water support missions. The responsibility of planning adequate and continuous water support is detailed. Operational concepts are described by temperate, tropical, artic, arid regions, and by various echelon levels. Appendices on requirements for new equipment, organizations, and training are provided. This pamphlet offers a good overall picture of water supply operation.

BRADC Report 2403
The Use of Geophysical Surface Methods for Military Groundwater Detection
May 1984

Purpose

The purpose of this report summarizes information on the use of surface-deployed geophysical methods for military groundwater detection developed by the Petroleum and Environmental Technology Division, Logistics Support Laboratory, US Army Belvoir Research and Development Center (BRADC), from 1975 to 1983.

Summary

Seven major indications have been drawn from the testing and evaluation during the study years. The first indication is that electrical resistivity and seismic refraction are the two geophysical techniques with the greatest near-term potential for success. Second, complementary seismic refraction and electrical resistivity surveys generally can be used for groundwater detection when the water table occurs in unconsolidated sediments and generally can not be used successfully for detection of groundwater in confined aquifers. Several other conclusions drawn from the testing are that commercially available software, equipment, and microcomputer systems enhance success. Perhaps the most significant factors affecting the probability of success are skilled, knowledgeable personnel to conduct the surveys.

CERL-TR-M-287
Theater of Operations Construction in the Desert: A Handbook of Lessons Learned in the Middle East
January 1981

Purpose

The purpose of this interim report is to consolidate available lessons learned on material, equipment, planning and design, and [illegible] by planners and builders for theaters of operations in the desert [illegible] Southwest Asia (SWA). It was compiled by the US Army Construction Engineering Research Laboratory.

Summary

The topic areas reviewed are: base design, base protection, electrical generation and distribution, water, vertical and horizontal construction, and engineer work factors. Of particular interest is Chapter 5, which addresses water resources problems. This chapter specifically treats water supply, distribution, treatment, and solid waste treatment.

CERL-WES
Troop Construction in the Middle East
October 1982

Purpose

The purpose of this report is to consolidate all engineer-related aspects of problems in base development and provide planners and engineers with a single source handbook covering construction problems and practices unique to the Middle East.

Summary

This report covers the various engineering disciplines involved in base development. These include base planning and siting, base protection, electrical generation and distribution, water supply, distribution and disposal, vertical construction, horizontal construction, and port construction. Factors affecting the engineer work force are also considered. Chapter 5, "Expedient Water Conservation Techniques," identifies practical and expedient water conservation measures that can help reduce the logistical burden of water supply in SWA. It also summarizes the near-term water supply concept for arid regions. Perhaps the greatest asset of Chapter 5 is the breakout of all major water requirements for major Army missions.

DMS No. Student Text (ST) 25
Stream Hydrology
March 1980

Purpose

The purpose of this text is to introduce terrain analysis students to the topic of stream hydrology.

Summary

This text is divided into three sections. The first section opens with a discussion on the origin of streams and proceeds to the basic properties of stream flow, velocity, discharge, flow and channel adjustment and channel shape. Section II disucsses hydrologic measurements, channel roughness, slope, and hydraulic radius. The final section closes with a discussion of flow frequencies. This text gives a brief, basic, easy to understand introduction to the topic of stream hydrology.

ETL-TAC MISC 01-85
User Requirements Analysis for the Worldwide Water Resources Data Base
January 1985

Purpose

This report describes a user requirements analysis which was undertaken to define and prepare a worldwide water resources data base (WRDB).

Summary

This rpeort addresses the user requirements analysis phase. It describes the survey and analysis conducted to determine military users needs in terms of data, reports, and access to the computerized data base. It summarizes the concept and structure of the operating system and data base, and describes the components of a proposed data base that will provide evaluated information on the quantity, quality, and availability (including location) aspects of water sources and facilities in terms responsive to the users' varied needs. The report gives a generalized description of the computer systems and operating environment suitable for servicing the DOD requirements. It also outlines an illustrative work program for the continued design, data base development, and system-implementation phases during fiscal years 1985 and 1986.

ETL Technical Report 0207
Terrain Analysis Procedural Guide for Geology
November 1979

Purpose

The purpose of this guide is to provide the Army's terrain analysts with step-by-step procedures for collecting, recording, and graphically presenting geologic and rock type information from sources such as maps, literature, and aerial imagery.

Summary

This report provides the methods and procedures necessary for obtaining information on geology from the most accessible sources, which are topographic maps and aerial photos. The report is written for the US Army terrain analyst, and presents the detailed methodology necessary for obtaining approximately 13 geologic data elements useful in preparing factor overlays. This report does not deal directly with military hydrology. However, it is useful from the standpoint that surface drainage pattern interpretation techniques are utilized as a key to geologic and potential hydrologic units.

ETL Technical Report 0285
Terrain Analysis Procedural Guide for Drainage and Water Resources
April 1982

Purpose

The purpose of this guide is to provide the Army's terrain analyst with step-by-step procedures for extracting, reducing, and recording drainage and water resources information.

Summary

This document is one in a series of terrain analysis procedural guides being written specifically for US Army terrain analysts, and presents the methodology for extracting, reducing, and recording information for drainage and water resources data. These data are divided into three subfields: (1) watercourses and water bodies, (2) drainage basins, and (3) groundwater. Step-by-step procedures are provided for producing a factor overlay and supporting data tables for each of the drainage and water resources data fields. This guide is a good cookbook treatment of water resources analyses techniques. Coverage of surface and groundwater procedural, analysis, and interpretative techniques gives a clear picture of the water resources input required for a complete picture of military hydrologic factors.

ETL Report 0344
Synthesis Guide for River Crossings
October 1983

Purpose

The purpose of this guide is to provide the terrain analyst with a method for evaluating watercourse segments for suitability as river crossing areas.

Summary

A deliberate river crossing is characterized by a deliberate pause at the entry bank for a build-up of forces and equipment. This synthesis guide evaluates two primary factors that influence the planning of a river crossing: the river and terrain. The physical characteristics of the river itself and the aspects of the nearby terrain that interact with and influence the river crossing are examined. Methods for extracting, evaluating, and presenting watercourse data are provided.

HEC Technical Paper 92
Hydrologic Engineering Center Planning Models
December 1983

Purpose

The purpose of this technical paper is to document the programs and work available for use by the general community.

Summary

In response to the needs of US Army Corps of Engineers professionals, the US Army Hydrologic Engineering Center (HEC) has developed and supports a family of computer programs designed to aid the Corps in its work. These programs include catchment, channel, alluvial, and statistical process models; system operation models; plan evaulation models; and data management programs. These models individually and collectively have been used throughout the Corps. Plans includes improving existing models and converting them to execute on microcomputers. Additional HEC reports document previous efforts in the field of hydrology which relate directly to military hydrology. A listing can be obtained directly from HEC.

NCEL TR-1637
Desert Water Supply
June 1982

Purpose

The purpose of this report, published by the Naval Civil Engineering Laboratory (NCEL), is to define the water supply requirements and constraints facing the Marine Corps in desert tactical operations, and to identify technological alternatives for providing new capabilities in the mid- and long-term.

Summary

Water supply, treatment, storage, and distribution requirements were assessed in relation to notional Marine Corps structure and hypothetical desert scenarios to determine required capabilities and potential shortfalls in current assets. Although not an Army report, this report presents a good overall picture of desert water supply requirements and anticipated problems. The report takes a systems analysis approach to water supply, beginning with water supply sources, touching upon water treatment and storage, through to water distribution and water temperature control.

WES Report EL-79-6
Military Hydrology Series Reports 1-13
May 1979-June 1986

Purpose

The purpose of this series of reports is to document the efforts to develop an improved military hydrologic capability for the US armed forces. The emphasis is on application in the tactical environment.

Summary

These reports are oriented toward the development of an integrated methodology for rapidly locating and evaluating groundwater supplies, particularly in arid regions. Specific works include (1) the compilation of guidelines for the expedient location of water for human survival; (2) the development of remote imagery interpertation procedures for detecting and evaluating groundwater sources; (3) the adaptation of suitable geophysical methods for detecting and evaluating groundwater sources; and (4) the development of water-supply analysis and display concepts. (Full bibliographic citations are included in Annex B of this guide.)

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ANNEX B

BIBLIOGRAPHY OF SELECTED MILITARY HYDROLOGY LITERATURE

ANNEX B

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Adams, LTC L. M., and Jordon, MAJ Larry D., Operational Test of Near Term Water Support System (US Army Airborne Board, 1982).

Anderson, Monty J., A Prototype Decision Support System for the Location of Military Water Points (Georgia Institute of Technology, 1980).

Applegate, James K., Geophysical Detection of Groundwater (US Army Mobility Equipment Research and Development Command, 1981).

Applications of Hydrology in Military Planning and Operations, Military Hydrology Bulletin 1 (Military Hydrology R&D Branch, 1957).

Baldwin, G. V. and Mcguinness, C. L., A Primer on Ground Water (Department of the Interior, US Geological Survey, 1963).

Bandy, John T., Distribution of Water Use at Representative Fixed Army Installations, CERL-TR-N-157 (US Army Construction Engineering Research Laboratory, [CERL] 1983).

Bilton, M. S., Preliminary Study: The Second Line Transport Requirements for the Distribution of Water in a Division Area of Operations, DOA-A-NOTE-13 (Department of Defense, 1983).

Butler, Dwain K. and Llopis, Jose L., Assessment of Two Currently "Fieldable" Geophysical Methods for Military Ground Water Detection, Miscellaneous Paper (MP) EL-79-6 (Waterways Experiment Station [WES], 1984).

Butler, Dwain K., Assessment and Field Examples of Continuous Wave Electromagnetic Surveying for Ground Water, MP EL-79-6 (WES, 1986).

Calkins, H. W., Evaluation of an Automated Water Data Base for Support to the Rapid Deployment Joint Task Force (WES, 1981).

Cerjan, LTC Paul G., and Stroup, LTC Theodore G., Employment of the Engineer System in Arid Mountainous and Desert Areas -- A Concept Paper (US Army War College, 1981).

Cidras, MAJ Joseph M., The Airmobile Division Potable Water Requirements in a Desert Environment (Armed Forces Staff College, 1975).

Chow, V. T., Open Channel Hydraulics (McGraw-Hill, 1959).

Collins, J., A Quantitative Summary of Groundwater Yield, Depth, and Quality Data for Selected Mideast Areas (WES, 1982).

Minutes of Water Resources Management Action Group (WRMAG) Meeting (Deputy Chief of Staff for Logistics, 1984).

Cosme, 1LT C. L., To Determine the Best Method of Water Distribution for a Light Division in an Arid Environment (US Army Quartermaster School, Office of the Deputy Commandant for Combat and Training Developments, 1983).

Delaney, A. J. and Sellmann, P. V., Detection of Arctic Water Supplies With Geophysical Techniques, CR 79-15 (June 1979).

Desai, M., Aerial Profiling of Terrain to Define Stream-Valley Geometry -- Study Report, US Geological Survey Open File Report 76-672 (Charles Stark Draper Laboratory, 1976).

Dooge, J. C. I., "A General Theory of the Unit Hydrograph," Journal of Geophysical Research, 64 (2):241-256 (1959).

Drainage (Defense Mapping School, 1977).

Dziuban, LTC Stanley, W., "Rhine River Flood Prediction Service," The Military Engineer, (1945).

Dziuban, LTC Stanley, W., "Employment of Artificial Floods in Military Operations," The Military Engineer (1947).

Dziuban, LTC Stanley, W., "Techniques of Artificial Flooding in Military Operations," The Military Engineer (1949).

Dziuban, LTC Stanley, W., "Implications of Artificial Flooding in Military Operations," The Military Engineer (1950).

Evans, D. D., Hostetler, S. S., and Onyskow, L. P., "Existing Capabilities for Measurement and Forecasting of Soil Moisture by Remote Means," Hydrology and Water Resources (1977).

Fleming, G., Computer Simulation Techniques in Hydrology (1975).

Flood Prediction Techniques, Technical Bulletin No. 5-550-3 (Department of the Army [DA], 1957).

Ford, D. T. and Davis, D. W., Hydrologic Engineering Center Planning Models (Hydrologic Engineering Center [HEC], 1985).

Fore, CPT H. R., To Determine the Best Method of Providing Potable Water Support to Combat Units in an Arid Environment (US Army Quartermaster School, Office of the Deputy Commandant for Combat and Training Developments, 1983).

Fowler, CPT Delbert M., "Operations at Hwachon Dam, Korea," The Military Engineer (1952).

Giles, 1LT P. K., A Comparative Study of the Best Method to Provide Water Support to Brigade Maneuver Units in a Combat Environment (US Army Quartermaster School, Office of the Deputy Commandant for Combat and Training Developments, 1983).

Glossary of Geology (American Geological Institute, 1972).

Gray, CPT David E., To Determine the Best Method of Providing Emergency Water to Forward Elements in a Desert Environment (US Army Quartermaster School, Office of the Deputy Commandant for Combat and Training Developments, 1983).

Green, CPT Celia, To Determine The Best Method of Providing Cool Drinking Water to an Army Corps in an Arid Environment (US Army Quartermaster School, Office of the Deputy Commandant for Combat and Training Developments, 1982).

Ground Water Manual (Department of the Interior, 1981).

Henderson, F. M., Open Channel Flow (MacMillan Publishing Company, 1966).

Herschy, R. W., New Methods of River Gauging (Wiley, 1976)

Hess, CPT Larry J., To Determine the Best Method of Emergency Water Supply in a Tactical, Desert Environment (US Army Quartermaster School, Office of the Deputy Commandant for Combat and Training Developments, 1982).

Hubbard, Roger W., Water as a Tactical Weapon (US Army Research Institue of Environmental Medicine, 1980).

Hydrology Engineering Handbook Section (US Department of Agriculture, Soil Conservation Service, 1972).

James, Wesley P., Formulation of a Long Range Concept for Streamflow Prediction Capability, MP EL-79-6 (WES, 1980).

James, Wesley P. and Link L. E. Jr., Status and Research Requirements, MP EL-79-1 (WES, 1979).

Johnson, E. E., Groundwater and Wells (Johnson Division, UOP 1975).

King, H. W., Wisler, C. O., and Woodburn, J. G., Hydraulics (John Wiley and Sons Incorporated, 1948).

Langowski, J. F., Jr., Forecasting Water Use on Fixed Army Installations Within the Contiguous United States (Army Military Personnel Center, 1984).

Langowski, J. F., Bandy, J. T., Lang, L. E., and Smith, E. D., A Survey of Water Demand Forecasting Procedures on Fixed Army Installations, CERL-TR-N-85/07 (CERL 1985).

Lindsten, Don C., Development of US Army Reverse Osmosis Water Purification Equipment, BRDC-2413 (Army Belvoir Research and Development Center [BRDC], 1986).

Linsley, R. K., Kohler, M. A., and Paulhus, J. L. H., Hydrology for Engineers, (McGraw-Hill, 1982).

Maloney, Stephen W. and Bandy, John T., Emergency Water Supply Planning for Fixed Army Installations, CERL-TR-N-86/11 (CERL, 1986).

McKim, H. L., Water Resources by Satellite, MP 1090 (WES, 1978).

Merry, C. J., Hydrologic Forecasting Using LANDSAT Data, (US Army Cold Region Research Laboratory [USACRREL], 1983).

Messmore, Jeffrey A., Terrain Analysis Procedural Guide for Drainage and Water Resources (US Army Engineer Topographic Laboratories [ETL], 1982).

Miers, Bruce T., Precipitation Estimation for Military Hydrology (Atmospheric Sciences Lab, White Sands Missile Range, 1980).

Military Hydrology, Army Regulation (AR) 115-21 (Department of the Army, Headquarters [DA HQ], 24 March 1977).

Military Hydrological Status of the 319th Engineer Detachment (Terrain-Hydrology) (WES, 1977).

Minimum Requirements for Water Potability (Short and Long Term Use), OSTAG 245 (American-British-Canadian-Australian Armies Standardization Program, 1972).

Minimum Standards of Water Potability, STANAG 2136 (NATO, 1974).

Morgan, J. M. Jr., et al., Mathematical Modeling for Evaluation of Field Water Supply Alternatives (Arid and Semi-Arid Regions) (Virginia Military Institute [VMI] Research Laboratories, 1981).

Morgan, J. M., Sculley, J. R., Ciccone, V. J., Jamison, D. K., and Knapp, J. W., Mathematical Modeling for Evaluation of Field Water Supply Alternatives (Arid and Semi-Arid Regions (VMI Research Laboratories, 1981).

Newton, R. W., Microwave Remote Sensing and Its Application to Soil Moisture Detection, RSC-81 (Texas A&M University College Station, 1977).

Pabst, A. F. and Cermak, R. J., Measurement and Forecasting of Streamflow by Remote Means (HEC, 1977).

Pierce, CPT R. D., A Comparative Study of the Best Method of Cooling Drinking Water in Support of Army Echelons Corps-Size and Above in an Arid Environment (US Army Quartermaster School, Office of the Deputy Commandant for Combat and Training Developments, 1982).

Preventive Medicine, AR 40-5 (DA HQ, 1981).

Prevention, Treatment, and Control of Heat Injury, Technical Bulletin Med 507 (HQ DA, 1980).

Proceedings and Recommendations of the Subsurface Water-Detection Symposium (US Army Corps of Engineers, 1984).

Proceedings of the Groundwater Detection Workshop (WES, 1984).

Proceedings of the Military Hydrology Workshop, Technical Report EL-79-2 (WES, 1979).

Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 years (US Weather Bureau, 1961).

Requests for Climatological Support to Army Activities, DA Pamphlet 115-1 (DA HQ, 1983).

Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions, Army Regulation (AR) 70-38 (DA HQ, 1979).

Romig, P. R., Rodriguez B. D., and Powers, M. H., Geophysical Methodology Studies for Military Groundwater Exploration (Colorado School of Mines, 1983).

Russell, Orville R., and Zall, Linda, Landsat Imagery for Regional Groundwater Exploration Reprint 81-121 (American Society of Civil Engineers [ASCE], 1981).

Sanitary Control and Surveillance of Water Supplies at Fixed and Field Installations, Technical Bulletin Med 229 (DA HQ, August 1975).

Scofield, R. A., and Oliver, V. J., A Scheme for Estimating Convective Rainfall From Satellite Imagery (National Oceanic and Atmospheric Administration Technical Memorandum, 1977).

Sculley, J. R., Ciccone, V. J., Jamison, D. K., Knapp, J. W., Morgan, J. M., Jr., Mathematical Modeling for Evaluation of Field Water Supply Alternatives (Arid and Semi-Arid Regions) (VMI Research Laboratories, 1981).

Smith, CPT Michael J., A Comparative Study of the Best Method to Resupply Drinking Water to Soldiers in a Company-Sized Combat Unit in a Chemical Environment (US Army Quartermaster School, Office of the Deputy Commandant for Combat and Training Developments, 1982).

Smith D. W., Rapid Detection of Water Sources in Cold Regions -- A Selected Bibliography of Potential Techniques, SR 79-10 (USACRREL, 1979).

Stinson, D. L., A Review of Army Doctrine on Military Hydrology, MP EL 79-5 (WES, 1981).

Takemoto, 1LT Glenn H., To Determine the Feasibility of Establishing a Bulk Water Transportation Capability for the Airborne/Air Assault Divisions (US Army Quartermaster School, Office of the Deputy Commandant for Combat and Training Developments, 1982).

The Study of Army Logistics, AD-B953-790 (Deputy Chief of Staff for Logistics, 1981).

Theater of Operations Construction in the Desert: A Handbook of Lessons Learned in the Middle East, Technical Report M-287 (CERL, 1981).

Thomas, Claudine, A Statistical Summary of Groundwater Yield, Depth, and Quality Data for Selected Areas in the CENTCOM Theater of Operations, MP EL [illegible] (WES, 1984).

Thompson, Robert J., The Use of Geophysical Surface Methods for Military Groundwater Detection (Belvoir R&D Center, 1984).

Todd, D. T., Ground Water Hydrology (Wiley, 1966).

Viessman, W., Introduction to Hydrology (Don-Donnelley, 1977).

Viessman, Warren, Jr., Knapp, John W., Lewis, Gary L, and Harbaugh, Terence E., Introduction to Hydrology (Don-Donnelley Publisher, 1977).

Webster's New Collegiate Dictionary (G&C Merriam Co., 1980).

Wiesnet, D. D., Remote Sensing and Its Application to Hydrology (Wiley, 1976).

Williams, Jimmy R., and Hann, Roy W., Jr., HYMO: Problem-Oriented Computer Language for Hydrologic Modeling (US Department of Agriculture, 1973).

Wooslev, 1LT John T., Water Reuse for Bare Base Deployments to Southwest Asia (Air Force Engineering and Services Center, 1984).

Wu, I. P., "Design Hydtographs for Small Watersheds in Indiana," Journal of Hydraulics (ASCE, 1963).

Wurbs, Ralph A., State-of-the-Art Review and Annotated Bibliography of Dam-Breach Flood Forecasting, MP EL-79-6 (WES, 1985).

Wurbs, Ralph A., Comparative Evaluation of Dam-Breach Flood Forecasting Methods, MP EL-79-6 (WES, 1986).

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